Are there post-stopped nasals in Austronesian?*

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Acehnese (A), Sundanese (S) and other Western Austronesian languages of Indonesia have been claimed to share the property of having an unusual series of "post-stopped" nasals. This segment-type is argued to differ from a prenasalized stop in having a less significant oral portion, /n^{d}/ vs. /^{n}d/. We compare phonological and phonetic data of this reported segment-type from A & S with prenasalized stops in Tamambo and Erromangan (Oceanic languages of Vanuatu) and nasal-stop clusters in Pamona and Manado Malay (also Western Austronesian languages of Indonesia). We find that these sounds in A & S are neither distinct phonologically nor significantly different in their phonetic implementation from the nasal-stop clusters of Pamona and Manado Malay. We conclude that a category of post-stopped nasals is not warranted and consider the broader implications of this finding.

1. Introduction

A number of descriptions in the literature suggest that Acehnese and Sundanese and other Western Austronesian languages of Indonesia share the property of having a series of unusual nasal stops described as "funny", "postploded", "post-occluded", "orally released" or "post-stopped" (Durie 1985, Blust 1997, Maddieson & Ladefoged 1993, Long & Maddieson 1993, Ladefoged & Maddieson 1996). "Acehnese has a distinction between lightly nasal and heavily nasal consonants" (Durie 1985:15). "In some Indonesian languages, and possibly in certain styles of speaking in all Indonesian languages, voiced stops disappear following homorganic nasal consonants in the same word. . . ." (Court 1970:205). "The voiced plosives and affricates [in Iban] are often very gentle in this case, and the distinction by ear of *rambuq* 'a kind of flowering plant' and *ramuq* 'timber' may depend mainly on the absence of nasality from the final vowel of the first word" (Scott 1957:511).

These descriptions suggest that this segment-type has a fully nasal closure and only a brief plosive release (represented as N^{D}) and differs from a prenasalized stop (^{N}D) in having a less significant non-nasal portion. We will refer to these sounds as *post-stopped nasals*. The possible existence of this phonological segment-type raises a number of issues: 1. Are they unary segments as implied by the descriptions? 2. Does their relative internal timing differ from prenasalized stops or nasal-stop clusters in a systematic way? 3. Are these a distinct segment-type? Maddieson and Ladefoged (1993) draw a distinction between the cases described in Acehnese and Rejang where these segment-types are in contrast with "ordinary" nasals and those cases that appear to involve oral and nasal coarticulation. The reported cases of post-stopped nasals known to us fall into three groups:

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(1) Types of post-stopped nasals
   a. Underlying/historical NC clusters
      Reported in several Austronesian languages (Blust 1997), e.g. Sundanese (Robins 1957), Rejang (Coady & McGinn 1982), Acehnese (Durie 1985), Gayo (Eades 2005), Jambi Malay (Durvasula 2009, Yanti 2010)
   b. Allophones of plain nasals
      Reported in Chinese dialects (Chan 1987, Chan & Ren 1987)
   c. Allophones of plain voiced stops
      Reported in various South and Central American languages, e.g. Karitiana (Storto 1999)

In the first case, N^D is claimed to be a phonological element in contrast with both plain nasals and plain voiced stops, whereas in the second and third cases, there is a surface N^D as a result of articulatory phasing of nasal-oral gestures. We focus here on the Acehnese type, where these entities are found to be in contrast with both plain nasals and plain voiced stops.

These segment-types have elicited considerable interest due to the questions they raise for the typology of partially nasal segment types (Riehl & Cohn 2011). In this paper, we take a closer look at both this segment-type and these claims, by examining data from Acehnese and Sundanese and comparing them with the nasal-stop sequences in several other Austronesian languages. A comparison of Acehnese and Sundanese with both closely and less-closely related Austronesian languages means that at least historically these derive from common structures, important for reaching reliable typological conclusions. In section 2, we present relevant background, both phonological and phonetic, before turning to the phonological questions posed by this segment-type in section 3 and the phonetic realization of these cases in section 4. In section 5, we consider the implications of our findings in terms of both the perception of contrasts and potential pathways to historical change, and we conclude in section 6.

Throughout the paper we use the following terminology and representations.

Table 1. Terminology and representations used throughout paper

NC	**Unary NC**	**NC cluster**
Any sequence of nasal and oral elements, whether unary or cluster	Nasal and oral elements comprising a single entity e.g. Fijian /ⁿd/ /vuⁿdi/ *vudi* 'banana'	Nasal and oral elements comprising two entities e.g. English /nd/ /sɛndɚ/ *sender*
ND	^{N}**D** – prenasalized stop **N^{D}** – post-stopped nasal	**N-D**

2. Background

2.1 Phonological background: unary ^{N}C vs. cluster NC

In the phonological literature, a distinction is often drawn between unary NCs, usually described as prenasalized stops, and NC clusters. The NCs of Fijian and English nicely illustrate canonical unary vs. cluster cases respectively. The following table includes evidence used in reaching distinct conclusions about the phonological structure of NC sequences for these two languages.

Table 2. Contrasting characteristics of NCs in Fijian and English

Fijian (based on Schütz 1985)	**English**
•All voiced stops have preceding nasal: /^{m}b, ^{n}d, ^{ŋ}g/; */b, d, g/	•Nasals and obstruents occur independently: /d, n, nd, dn/
•NC occurs initially and medially [**^{m}b**onu] 't.o. eel' [so**^{m}b**u] 'down' [**^{n}d**evo] 't.o. stone' [vu**^{n}d**i] 'banana'	•NC can only occur where it will not violate sonority sequencing principles *se**nd**er, appe**nd**, *#**nd-***
•No consonant sequences other than voiced NC	•Range of consonant clusters
•All syllables are open	•Codas common in both medial and final position

As seen in table 2, in Fijian all voiced stops have a preceding nasal element; NCs occur syllable initially (including in word-initial position), but never finally; and the language does not allow clusters or closed syllables. These observations suggest that NCs function as single segments: the elements are inseparable (i.e. no plain voiced stops) and the phonotactics allow only for onsets (not, for example, medial heterosyllabic clusters that include a coda). The fact that the NCs can occur word-initially where a cluster would violate sonority is often taken as evidence for unary segmenthood, where presumably a single segment is not subject to sonority sequencing constraints. Riehl (2008) argues that this criterion for unarity is not deterministic in the absence of other evidence, but in the case of Fijian, it is in line with other evidence. In English, on the other hand, nasals and stops occur independently; NCs occur only where they will not violate sonority sequencing principles (Clements 1990), and various consonants clusters and codas are allowed. The observations about English suggest that NCs are no different from other consonant clusters observed in the language, and there is no reason to suspect that the sequences form a single unit, in contrast to the unary elements in Fijian.

While there is broad agreement in the literature that two different phonological NC types exist, based on languages like Fijian and English, the determination of NC status is much more difficult to make in some languages. The clearest unary cases are those where the nasal and oral elements are inseparable. The clearest cluster cases are those with full separability of the parts and phonotactics that allow for a range of clusters. Languages, for example, with NCs that are separable but where the syllable structure or morphology do not offer any clues as to their segmental status are more challenging to analyze. For the purposes of this paper, we accept that different phonological entities exist while acknowledging that it is hard to reach clear conclusions in some languages. We do not delve into the complexity of the broader issues unless they are necessary in describing a particular case. For further discussion and a proposed methodology for analyzing the phonological structure of a language's NCs, see Riehl (2008) and Riehl & Cohn (2011). One further complexity involves the status of NT sequences (that is, where the nasal is followed by a voiceless obstruent). Following Riehl (2008), we conclude that NTs are necessarily clusters. Thus for the comparison of post-stopped nasals, it is the ND cases, not the NT cases, that are of interest. For this reason we focus our discussion here on the voiced ND sequences.

2.2 Phonetic background: Unary ^{N}C vs. cluster NC

In this section, we introduce two phonetic characteristics of NCs that play a role in our analysis of the post-stopped cases. We address total duration in subsection 2.2.1 and relative nasal-oral timing in 2.2.2. (Methods and results for the present study are presented below in section 4.) This background discussion of four Austronesian languages, Tamambo and Erromangan (Vanuatu) and Manado Malay and Pamona (Indonesia) is based on results of phonetic analysis from Riehl (2008). (See also Riehl & Cohn 2011 for discussion of this issue.) Data from these four languages are also analyzed as part of the present study, alongside data from Acehnese and Sundanese, as summarized in the following table.

Table 3. Information on languages included in the study

Language	ND status
Tamambo (Vanuatu)	Unary: Prenasalized stop
Erromangan (Vanuatu)	Unary: Prenasalized stop
Manado Malay (Indonesia)	Cluster
Pamona (Indonesia)	Cluster
Acehnese (Indonesia)	Post-stopped nasal?
Sundanese (Indonesia)	Post-stopped nasal?

2.2.1 Total duration

A priori, we would expect differences in overall timing (total duration) between unary nasal-stop segments and nasal-stop clusters: In the unary case, the duration should be comparable to other segment-types (e.g. plain nasals and voiced stops) and in the cluster case comparable to other clusters. This assumption has often been expressed in the literature (see e.g. Herbert 1987). However, there have also been claims suggesting that this difference in phonological structure between unary segments and nasal-stop clusters is not systematically realized in the phonetics. For example, Downing (2005:183) states "There is no consistent phonetic contrast, like a durational distinction, between prenasalized stops and NC clusters." (See also Browman and Goldstein 1986, Maddieson & Ladefoged 1993 and Ladefoged & Maddieson 1996.)

Riehl (2008) addresses this question through a systematic phonological and phonetic investigation of four Austronesian languages containing different sorts of nasal-stop sequences. Contra the claims in the literature, Riehl finds strong support for the conclusion that there is a systematic difference in overall timing between unary cases (^{N}D) and clusters (N-D) whereby N-D is substantially longer than ^{N}D. She concludes that the best way to assess this difference is by looking at a ratio of the duration of a plain nasal to the duration of an NC sequence (nasal + oral): N:NC; for example the ratio of Manado Malay /ta**n**a/ 'earth' to /ta**nd**a/ 'sign'. This is illustrated in figure 1 for medial alveolar NDs where the average ratios are close to 1 for the unary cases and significantly greater than 1 (around 1.5 on average) for the cluster cases.[1] (See Appendix 1 for specific forms.)

[1] In the box plot, the solid black lines represent median values; the box represents the interquartile range, the whiskers represent the range of non-outlying data, and the circle represents an outlier.

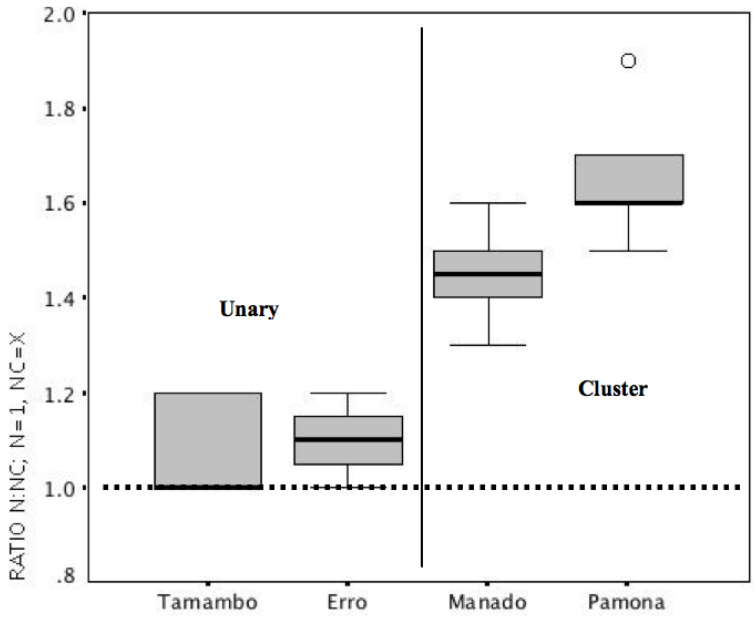

Figure 1. Total duration ratios of alveolar /n/ to /ⁿd, nd/ in two languages with unary segments and two with clusters, in medial position; averages across five speakers of Tamambo, four of Erromangan, six of Pamona and Manado Malay; ten repetitions per speaker. The duration of the plain nasal is /n/=1. (Adapted from Riehl 2008:266.)

This systematic difference in the unary vs. cluster cases holds for the four languages under investigation. It holds for all speakers, across different word positions and places of articulation. It is also consistent with prior observations in the literature for those cases where the phonological structure of the NCs is not debatable (e.g. the prenasalized stops of Ndumbea, Gordon & Maddieson 1999, and the clusters of English, Vatikiotis-Bateson 1984).

In light of these robust conclusions, we might wonder why there have been contradictory conclusions in the literature. We believe four methodological issues account for this earlier confusion. First is the question of how the comparisons are made across languages and speakers. Many past studies compared absolute durations both across languages and speakers resulting in misleading conclusions. In fact, the only valid comparisons across languages and speakers are relative measures such as ratios. Second is the issue of what types of segments are compared. In many past studies NC durations were compared to the duration of plain voiceless stops rather than plain nasals, which is misleading as there are further structural and phonetic differences in voicing and aspiration. Third, there is a need for sufficient data, both in terms of multiple repetitions and multiple speakers. Many past studies make use of only one or two speakers or repetitions, which may be problematic, especially since, as we will see below in section 4, some speakers exhibit considerable variability, and there are also subtle, but systematic, differences between speakers. Finally, it is critical that there be independent phonological evidence supporting the analysis of the types being compared. Riehl (2008) finds that if each of these methodological issues is addressed, a systematic and robust difference between NC types holds.

2.2.2 Relative internal timing

In addition to differences in total duration, we might also expect differences in the relative timing of the nasal and oral components of the sequence. In the case of a cluster, which

is a sequence of two separate segments, a priori we assume that roughly the first half of the sequence is nasal and the second half is oral. In the case of a prenasalized stop, on the other hand, we might expect a brief nasal onset with a more substantial oral portion, a scenario reflected in the common notation for these sounds: ^{N}D. Finally, in the case of a post-stopped nasal, we might expect to find a segment that is primarily nasal followed by only a brief oral portion, an assumption also reflected in the notation: N^{D}.

Riehl (2008) measured the nasal and oral components of the four languages discussed in 2.2.1. For both the prenasalized stops and the nasal-stop clusters, the observations were different from the expectations. The ND sequences in all four languages had roughly the same internal timing patterns whether unary or cluster, regardless of their differences in total duration: the sequences were primarily nasal with only a brief non-nasal portion. The following figure contains spectrograms of words with plain nasals and ND sequences in Tamambo and Manado Malay.

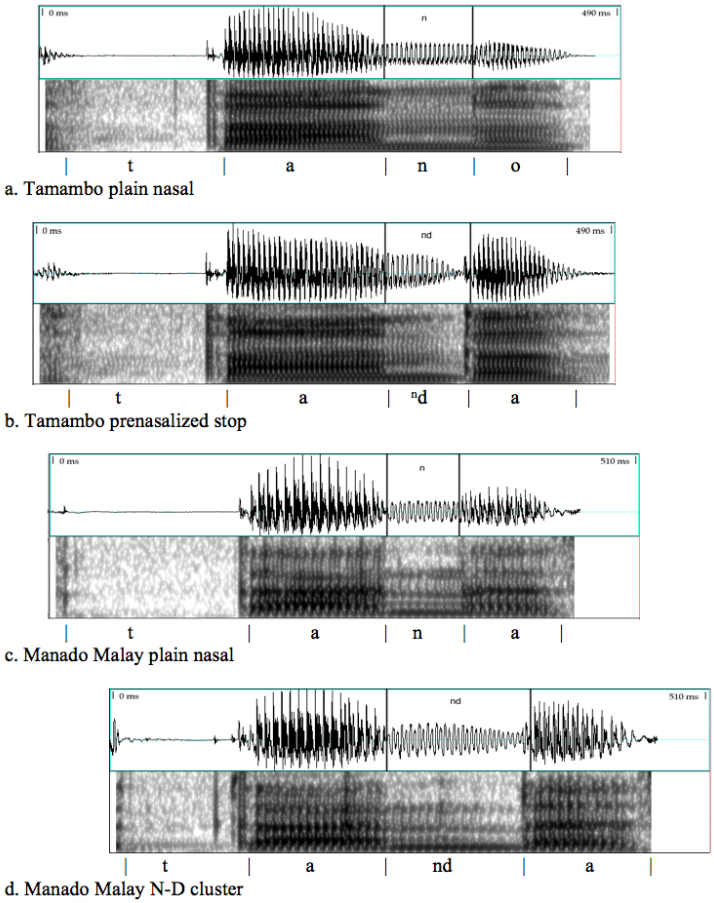

Figure 2. Spectrograms of Tamambo /tano/ 'garden' (a), Tamambo /taⁿda/ 'to look up' (b), Manado Malay /tana/ 'earth' (c) and Manado Malay /tanda/ 'sign' (d) (modified from figures 5.1 and 5.2 in Riehl 2008:180). Spectrograms are lined up so that the onsets of the nasals coincide

In figure 2, spectrogram (b) is a token of /taⁿda/ 'to look up' from Tamambo containing a prenasalized stop while (d) is a token of /tanda/ 'sign' in Manado Malay containing an N-D cluster. In both cases, the duration is almost entirely nasal with only a brief plosive release, despite the fact that the cluster in Manado Malay is approximately twice as long as the prenasalized stop in Tamambo. A plain nasal from each language is included for

comparison (a. Tamambo, c. Manado Malay). (Information on how measurements were made for the present study is in section 4.4.)

Data from a representative speaker of each of the four languages is displayed in figure 3 below. This graph illustrates the observation that all NDs, regardless of phonological status, are almost entirely nasal. It also illustrates the observation about total duration discussed in section 2.2.1: N-D clusters are longer than unary ^{N}Ds. The N-Ts are also included here. They differ from the NDs in a number of interesting ways. First in all four languages they are significantly longer, consistent with Riehl's (2008) conclusion that they are always clusters, irrespective of the unary or cluster status of the NDs in the particular language. Second unlike the NDs where the oral portion (non-nasal closure and plosive release) is negligible, in all four languages the N-Ts have a robust oral portion. In other words, the phonetic timing of N-Ts corresponds quite closely to the expectations based on phonological structure. For the remainder of the paper we focus our attention on the NDs. For further discussion of N-T's see Riehl and Cohn (2011) and Cohn and Riehl (2012).

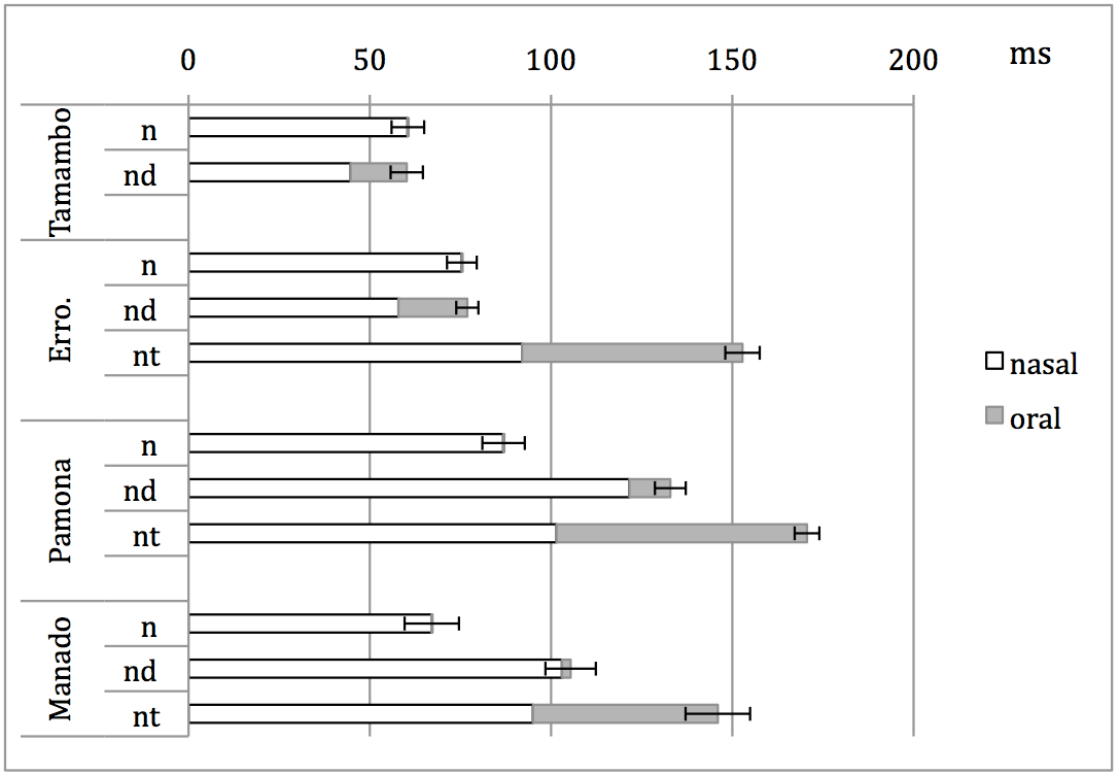

Figure 3. Average durations in milliseconds of nasal and oral portions of /n/, /n^{d}, nd/ and /nt/ across ten repetitions for one representative speaker of each language

In summary, despite our expectations, the relative nasal-oral timing in all ND sequences is highly similar. Sequences are primarily nasal followed by only a brief non-nasal closure or plosive release. This is the case whether the sequence is a cluster with a total duration roughly equivalent to other clusters in the language or whether the sequence patterns as a single segment composed of two phonetically distinct parts.

2.3 Summary

In this section, we argued that there are two distinct ND patterns in the phonology: unary ^{N}Ds and cluster N-Ds. We then provided an overview of the phonetic characteristics of these two different phonological types. Unary and cluster NDs differ from one another in

terms of total duration: unary ^{N}Ds are comparable in duration to single segments, while clusters are substantially longer. In terms of internal timing, however, unary and cluster NDs share the same phonetic characteristics: all NDs are primarily nasal followed by only a brief non-nasal release. Figure 4 summarizes the findings in this section.

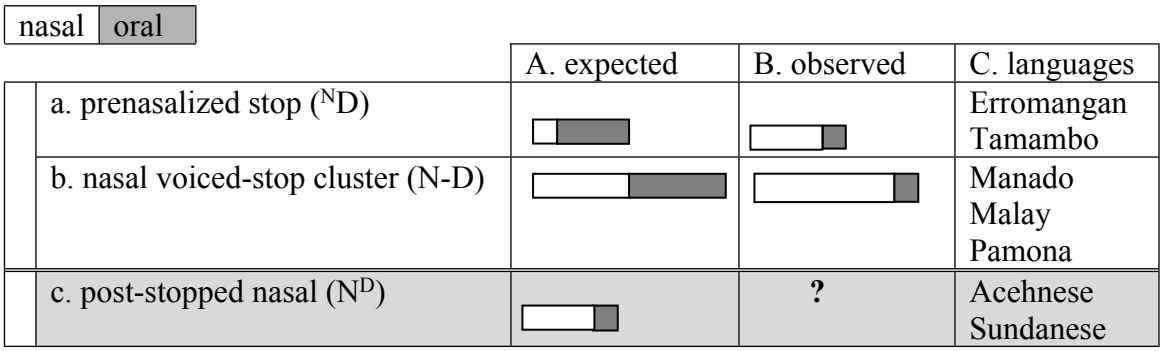

Figure 4. Expected and observed phonetic timing relationships of ND sequences

In figure 4, we compare the expected and observed patterns for unary prenasalized stops and nasal voiced-stop clusters based upon the data presented here. We include the expected representation of post-stopped nasals in (c) but will argue in section 4 that this type is not attested. (Note that we do not consider a hypothetical unary case with equal nasal-oral portions as this has not been attested in the literature.)

3. Phonology of post-stopped nasals

Following the discussion so far, the first question we ask with respect to the structure of the NDs in Acehnese and Sundanese is whether their phonological patterning suggests that the sequences are unary entities or clusters. The characterization of these NDs in the literature as "post-ploded", "post-stopped" or "funny" implies that they are unary segments, but we need to examine the evidence to see if this is indeed the case. Table 4 provides an overview of ND patterning in each language, along the lines of that presented for Fijian and English in table 2.

Table 4. Phonological characteristics of NCs in Acehnese and Sundanese as compared to English vs. Fijian-like phonological properties

	Sundanese	**Acehnese**
Independence of elements:	• Nasals and obstruents occur independently: /d, n, t/	• Nasals and obstruents occur independently: /d, n, t/
Phonotactic distribution of ND:	•Medial only	•Medial •Initial - marginal
Presence of other consonant clusters:	• Tautosyllable stop-liquid • Heterosyllabic NT, liquid-obstruent	• Tautosyllabic stop-liquid • ND initial (NT with prothetic vowel) • Heterosyllabic NT, liquid-obstruent
Allowable syllable types:	• Codas common in both medial and final positions	• Codas common in both medial and final positions

In both cases, observed patterns are more like English than Fijian.

First we consider Sundanese. As seen table 4, in Sundanese, nasals and stops occur independently and word-final codas are common. While stop-liquid clusters occur initially and medially (there are no final clusters), NDs only occur word-medially. Further, the distribution of NDs completely parallels that of NTs, which no one has ever suggested are anything but clusters. The phonological patterning of NDs in Sundanese appears very similar to that found in Manado Malay where NDs occur only medially and are heterosyllabic (Riehl 2008). There is really no evidence to suggest that the NDs in Sundanese are anything but clusters, beyond the labels used to describe these entities in some of the secondary sources. Robins (1957:FN 1), despite often being cited as providing evidence that these are a special segment-type, is very clear that NDs are sequences of two consonants: "Within a word, *intervocalic sequences* of nasal consonant followed immediately by a homorganic voiced plosive or affricate are frequently pronounced with a very light articulation of the non-nasal consonant (i.e. mb [m^{b}], ŋg [ŋ^{g}], nd [n^{d}], ndʒ [n^{dʒ}]. . .)." [Emphasis added.] Thus what may be special is not the phonological structure of these sequences, but rather their phonetic realization.

Acehnese exhibits patterns similar to but not identical to Sundanese. In this language, nasals and stops occur independently and word final codas are common; NDs occur primarily medially but with a limited number of word-initial forms. Again their distribution closely parallels that of N-T clusters. A sense of how limited these are can be gleaned from comparing the distribution of initial voiced stops, voiceless stops, plain nasals, and NDs and NTs based on the roughly 3,700 item wordlist presented by Daud & Durie (1999). (Initial NTs are written with a preceding <eu> [ɤ] which is usually not pronounced except in careful speech.)

Table 5. Number of nasals, stops and NC sequences occurring word-initially in Acehnese based on Daud and Durie's (1999) wordlist of approximately 3,700 items

	voiceless stop	voiced stop	nasal	ND	(<eu>)NT
labial	388	300	260	4	5
dental	343	93	77	0[2]	5
velar	419	217	17	1	4

Durie (1985) analyzes Acehnese NDs as unary, referring to them as "funny" nasals. This treatment is picked up by Long and Maddieson (1993), Blust (1997) and others.[3] Durie's main motivations for the proposed unary analysis stem from phonotactic arguments and the general goal of offering a phonemic analysis of nasalization. In fact he concludes that if a strictly phonemic analysis is given, then the source of the contrast should be taken to reside in the orality or nasality of the following vowel with the "funny" nasals taken to be allophones of plain nasals. We return to this point briefly in section 5. However, our interpretation of the phonotactic evidence leads us to the opposite conclusion, that the NDs are best treated as clusters. As observed by Durie, it is difficult to provide a strictly phonemic analysis of Acehnese, as there are a very small number of forms that challenge

[2] The initial /nd/ form used in our phonetic study was known by the consultant who assisted in preparing the word list but did not appear in Daud and Durie's (1999) list.

[3] Long and Maddieson (1993) describe four consonant series for Acehnese: plain stops, plain nasals, orally-released nasals (the *NDs* under discussion here) and also nasal + stop. This final case, at least in the example given, *mandum* 'all' is a case of a nasal + stop across a morpheme boundary, *man* 'all' + *dum* 'much, many' in contrast to the word-internal medial case.

otherwise general phonotactic patterns. The close parallels between phonotactic patterns observed for ND and NT – the latter clearly being clusters – suggest a unified treatment of these cases as clusters, in line with the later analysis assumed by Daud and Durie (1999:6-7).

The situation in Acehnese is reminiscent of the situation in Pamona, where NDs occur word-initially but are quite limited in their distribution, in contrast, for example, to the unary cases in Tamambo and Erromangan, where initial ^{N}Ds are abundant. In addition, as will be seen below, the durational properties for initial and medial NDs in Pamona support a unified treatment of these cases, and Riehl (2008) argues that the NDs, while clearly tautosyllabic, are nevertheless clusters. More generally, Riehl questions a widely held assumption that NCs occurring word initially (and hence non-ambiguously in syllable-initial position) are necessarily unary, since otherwise such clusters would violate sonority sequencing principles. Given that sonority violations are well-attested cross-linguistically (Clements 1990), this should not be the sole criteria for determining syllabification. Adisasmito-Smith's (2004) analysis of Javanese, another W. Austronesian language of Indonesia, also provides support for the analysis of NDs as tautosyllabic clusters. She shows that this is the simplest analysis medially and highlights the fact that initial NDs are quite rare and occur mainly due to N prefixation in the active form of verbs.

Now that we have concluded that the NDs in Sundanese and Acehnese are phonologically clusters, we return to the question of their phonetic characteristics in section 4. As clusters, do the N-Ds in Sundanese and Acehnese share the same total duration and internal timing patterns as the clusters in Manado Malay and Pamona?

4. Phonetics of post-stopped nasals

In this section, we present the results of our phonetic studies of the ND sequences in Acehnese and Sundanese and compare them with the other four languages under discussion. In 4.1, we explain our methodology; in 4.2 we present total duration results, and in 4.3 we discuss relative internal timing, including a more detailed look at the internal timing properties of all six languages.

4.1 Methodology

In order to determine whether or not the N-D sequences in Acehnese and Sundanese differ phonetically from NDs in other languages, whether unary or clusters, we compare their phonetic realization to four other Austronesian languages as discussed in section 2: Tamambo and Erromangan, which have unary ^{N}Ds, and Manado Malay and Pamona, which have N-D clusters. Details of the wordlists, number of speakers and number of tokens are presented in Appendix 1.

In this section, we focus on data for voiced alveolars in medial and initial word position. A contrast between medial /n/ and ND is present in all six languages and a contrast between initial /n/ and ND occurs in all of the languages, except Sundanese where no initial NDs are found. However, while common in Tamambo and Erromangan, the initial sequences are marginal in Acehnese and Pamona and occur in only a single form in Manado Malay.[4] All words were bisyllabic, except for initial forms in Acehnese and

[4] In the case of Manado Malay, there is only one initial /nd/ form known to us – [ndaʔ], which is a variant of [tidaʔ] 'no, not'. We therefore characterize the language as not allowing initial NCs; however, we include phonetic analysis of this single form as we seek to learn more about the possible range of ND properties more generally.

Manado Malay that were monosyllabic. These forms were mixed with filler words and placed in frame sentences. Speakers produced the target items ten times, either with a written prompt or by repeating the sentences after prompting from another native speaker.

Although the recording set-up varied slightly by language and recording session, all of the recordings were made with a Marantz PMD670 digital recorder and Shure SM-10A headset microphone. Recording took place either in a sound proof booth or in relatively quiet locations as sound proof facilities were not available.

Analysis was undertaken with Praat (Boersma and Weenink 2014). We took the following duration measurements for each token word, where applicable: total ND sequence, nasal steady state, nasal transition, non-nasal closure and oral burst. Total ND duration was easily determined. We discuss the other measurements further in section 4.3 below. We turn first to the results of total duration in 4.2 and then the finer details of the internal timing in 4.3.

4.2 Total duration of post-stopped nasals

In section 2, we illustrated that unary and cluster NCs differ phonetically in their total duration: prenasalized stops are comparable in length to plain nasals while N-D clusters are approximately 1.5 times the length of a plain nasal. If the "post-stopped nasals" of Acehnese and Sundanese are unary segments, as suggested in some of the prior literature, then we would expect them to have a total duration comparable to a plain nasal, similar to the ^{N}Ds in Tamambo and Erromangan. If they are instead clusters, as we argue in section 3 based on phonological evidence, then we would expect them to have a total duration approximately one and a half times that of a plain nasal, similar to the N-Ds in Manado Malay and Pamona. In figure 5 below, we present the total duration data of NDs in Acehnese and Sundanese, alongside NDs from the other four languages. Each letter represents the average N:ND ratio for one speaker. We compare medial data for all six languages and initial data for all but Sundanese.

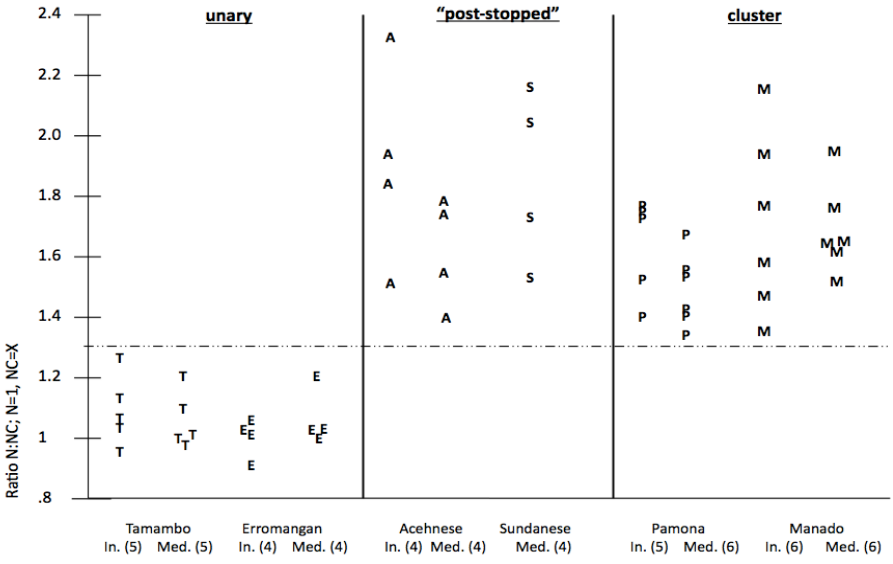

Figure 5. N:ND total duration ratios in initial (In.) and medial (Med.) position for six languages. N = 1, ND = X. Each letter represents the average ratio for a single speaker based on ten repetitions each of the N and ND forms

As can be seen in figure 5, the Acehnese and Sundanese data clearly pattern with the data in the cluster languages rather than the unary languages. In the unary languages of

Tamambo and Erromangan, the N:ND ratios ranges from .89 to 1.28 across the speakers. In the cluster languages of Pamona and Manado Malay, the N:ND ratios range from 1.34 to 2.21 across the speakers. In Acehnese, the N:ND ratios fall between 1.36 and 2.35 while in Sundanese the ratios fall between 1.39 and 2.19. The line on the graph at 1.3 illustrates that there is no overlap between the ratios in the unary languages and those in cluster languages, with Acehnese and Sundanese clearly falling into the cluster category.

There is an interesting observation regarding the initial cases. In Tamambo and Erromangan, where the initial cases are quite common, the timing patterns are very similar to the medial cases. On the other hand in Manado Malay and Acehnese where the initial cases are particularly rare, the range of N:ND ratios across speakers is greater, suggesting that these patterns are less stable and less consistent than the initial cases in Tamambo and Erromangan. (A greater range of N:ND ratios is also observed for the medial Sundanese cases, although it is difficult to lend any significance to this in the absence of initial sequences in the language for comparison.)

The phonetic data from total duration supports the conclusion that the NDs in Acehnese and Sundanese are indeed clusters. This is consistent with the phonological analysis and the historic source of these ND sequences. Our findings are also consistent with Durie's (1985:15) observation for Acehnese that the total duration of these "post-stopped" cases is in excess of the duration of a single segment: "The initial funny nasals are characterized acoustically by a longer duration than the initial plain nasals."

Since we have concluded that the NDs in Acehnese and Sundanese are clusters, the question at hand is not whether these so-called "post-stopped" nasals are distinct from prenasalized stops; they differ from the prenasalized stops of Tamambo and Erromangan in the same ways that Pamona and Manado Malay do, by being of longer duration. The question now is whether they are distinct from other N-D clusters. Is there something special about their phonetic realization that accounts for the oft-cited observations about their unique internal composition? In other words, is there evidence that they constitute a distinct phonetic type of NC sequence? We turn to this question in the next section where we consider the relative internal timing of post-stopped nasals as compared to prenasalized stops and clusters.

4.3 Relative internal timing of post-stopped nasals

We have established, on the basis of both phonological patterning and total duration, that the ND sequences in Acehnese and Sundanese are clusters rather than unary segments. We now turn to the issue of relative internal timing. How do the relative nasal-oral timing patterns of Acehnese and Sundanese compare with the patterns in our other four languages? Figure 6 below includes data for Acehnese and Sundanese alongside data from the other cases (as presented in figure 3).

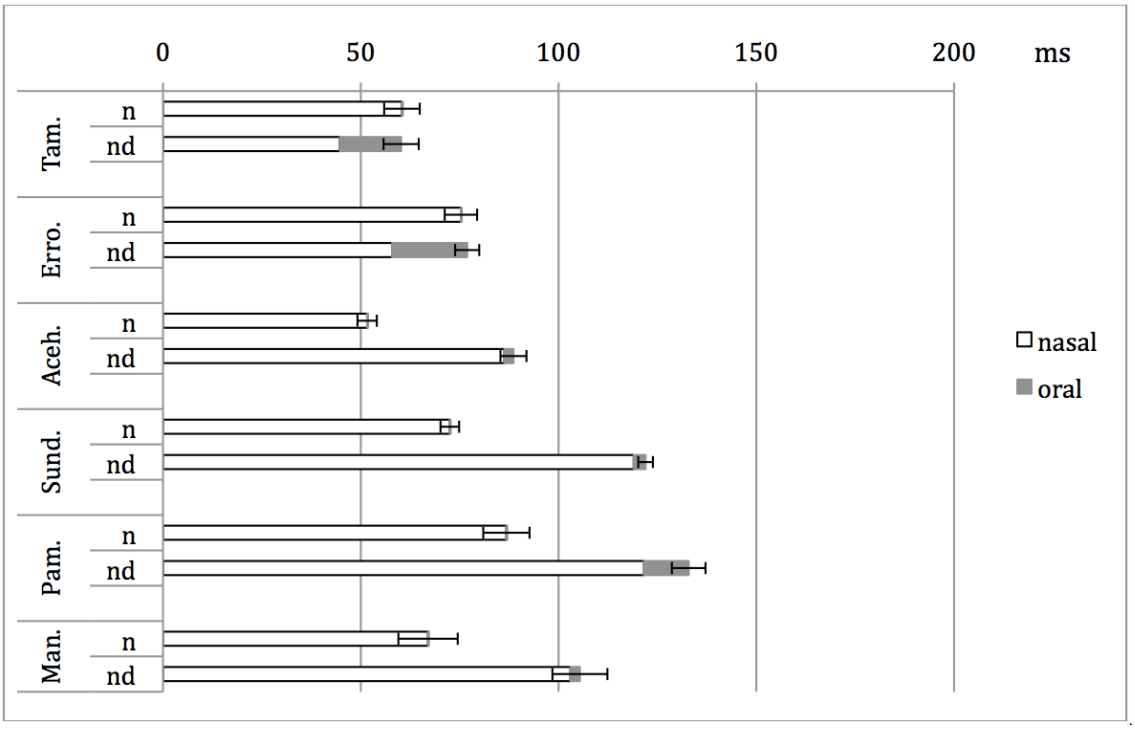

Figure 6. Average durations in milliseconds of nasal and oral portions of plain nasals and ND sequences in six languages across ten repetitions for one representative speaker of each language. (Data for four languages repeated from figure 3.)

The average durations of the oral portions for the N-Ds in Acehnese and Sundanese are very brief, at only several milliseconds each. This pattern is indistinguishable from that observed in Pamona and Manado Malay and similar to Tamambo and Erromangan which also have relatively brief oral portions.

Previous descriptions of Acehnese and Sundanese in the literature highlight the negligible non-nasal closures of the NDs, descriptions that led to the characterization of the sequences as post-stopped. For example: "Within a word, intervocalic sequences of nasal consonant followed… by a homorganic voiced plosive… are frequently pronounced with a very light articulation of the non-nasal consonant… In such cases the absence of nasality in the vowel following the plosive or affricate was found to be a more readily noticeable mark of the nasal+voiced consonant sequence as distinct from a single intervocalic nasal consonant" (Robins 1957:91, discussing Sundanese). "The combinations *mb, nd, nj, ngg* tend to be merged in speech, so that for example *banda* is pronounced *bana....* but without the strong nasal effect on the following vowel which an ordinary nasal has" (Daud and Durie 1999:6-7, discussing Acehnese). These observations are borne out by the data in figure 6. However, it turns out that this pattern applies not only to the presumed aberrant NDs of Acehnese and Sundanese but to the N-D cluster patterns in Manado Malay and Pamona and the unary ^{N}D patterns in Tamambo and Erromangan as well. In fact, this pattern, whereby NDs are primarily nasal with only a brief oral portion, appears to be the typical pattern for both N-D clusters and prenasalized stops, and is observed in all cases known to us.

4.4 Microtiming

Our study thus far leads us to the conclusion that Acehnese and Sundanese NDs do not constitute a unique sequence-type but rather have the phonological and phonetic

properties of N-D clusters. This leads to the question of whether the Acehnese and Sundanese sequences differ in any systematic way in the details of the relative timing or oral burst structure from typical N-D clusters. Is there something else that distinguishes Acehnese and Sundanese N-Ds from the other nasal-voiced stop clusters, some other difference that we have not yet observed? To answer this question, we examine the phonetic properties of these sequences in more detail, at a level we refer to as *microtiming*. Detailed study of this kind on NDs has not, to our knowledge, been done previously. Therefore, we include a full discussion of our methods and results even though our findings are ultimately negative – in that microtiming does not serve to distinguish these cases.

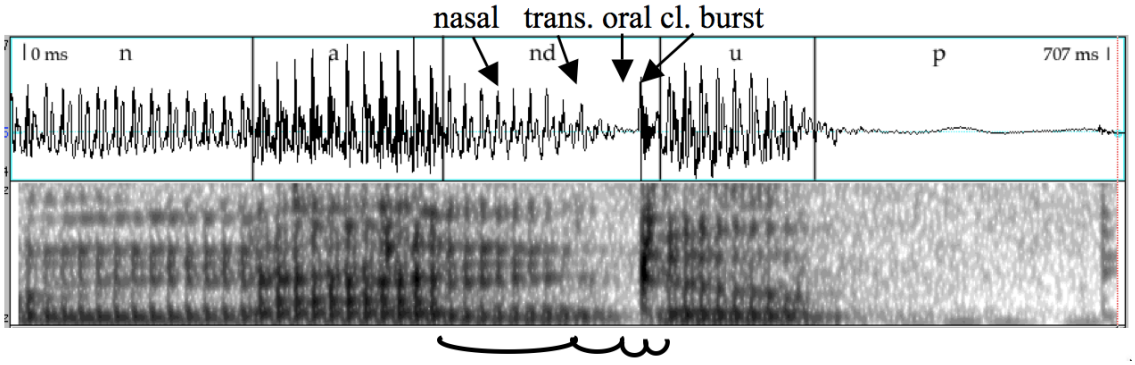

Figure 7. Illustration of microtiming labels in a token of Erromangan [naⁿdup] 'bead tree'

Figure 7 contains a representative token of Erromangan /naⁿdup/ 'bead tree', illustrating the microtiming details of a prenasalized stop. Rather than divide the ND solely into nasal and oral portions, we have labeled the following: *nasal* (the steady state nasal portion), *transition* (the portion of the nasal where a decline in nasality is observed in anticipation of the oral component), *oral closure* (the portion of the closure that exhibits no nasality), and *burst* (the release of the oral closure until the onset of the following vowel).

We have labeled and calculated microtiming results for four speakers of each of our languages. In order to focus on the microtiming details rather than the issue of total duration, which we already resolved in section 4.2, we display only the results for the transition, oral closure and burst. Including the duration of the steady nasal portion does not inform the comparison and only serves to distract since the variation in nasal duration is dependent upon the phonological unary or cluster specification.

The questions we need to address are whether there are relevant differences between speakers, between languages and between types of languages. We take up these questions in turn. Figure 8 below displays the microtiming results for each of the six languages by speaker. The results are arranged from shortest to longest combined duration of the nasal transition, oral closure and release.

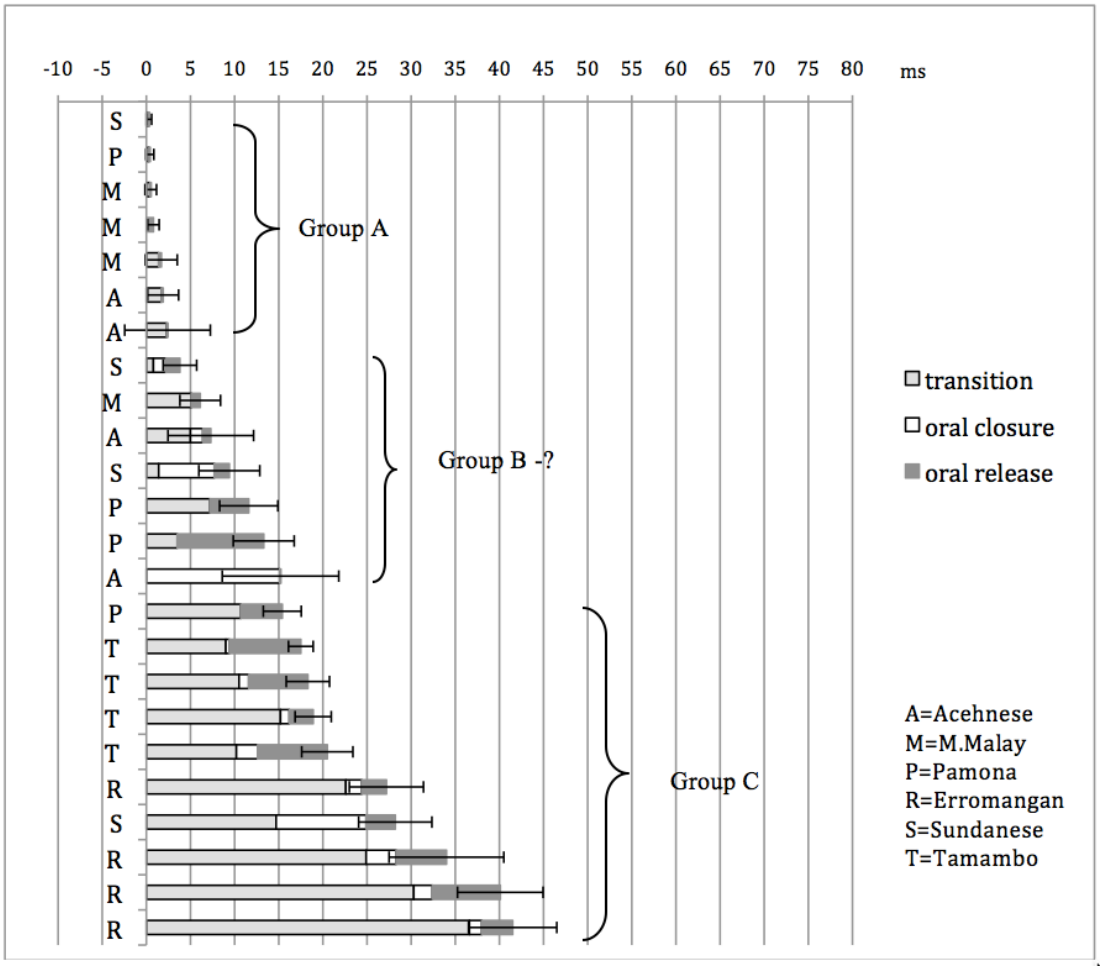

Figure 8. Microtiming results for medial alveolar NDs for four speakers of each language, averaged over ten repetitions per speaker. Languages can be identified by initial letter, except "Erromangan" which is represented by "R". Error bars display standard deviation from mean total duration of microtiming elements.

Figure 8 reveals that ND microtiming patterns appear to fall along a continuum from little or no transition, oral closure or release to substantial transition, notable oral closure and clear release, the average total duration of the three combined parts ranging from 2 to 41.5 milliseconds. We have made an attempt to group these results into different categories, as indicated by the brackets on the left. Group A includes NDs with no oral portion. Group C includes tokens with notable transitions (decrease in nasality) and a clear oral closure or burst. The cases in between – Group B – are harder to characterize. These have either a robust oral portion (closure and/or burst) or at least a brief transition and brief oral portion.

Figure 9 provides sample spectrograms illustrating the three different patterns identified in figure 8.

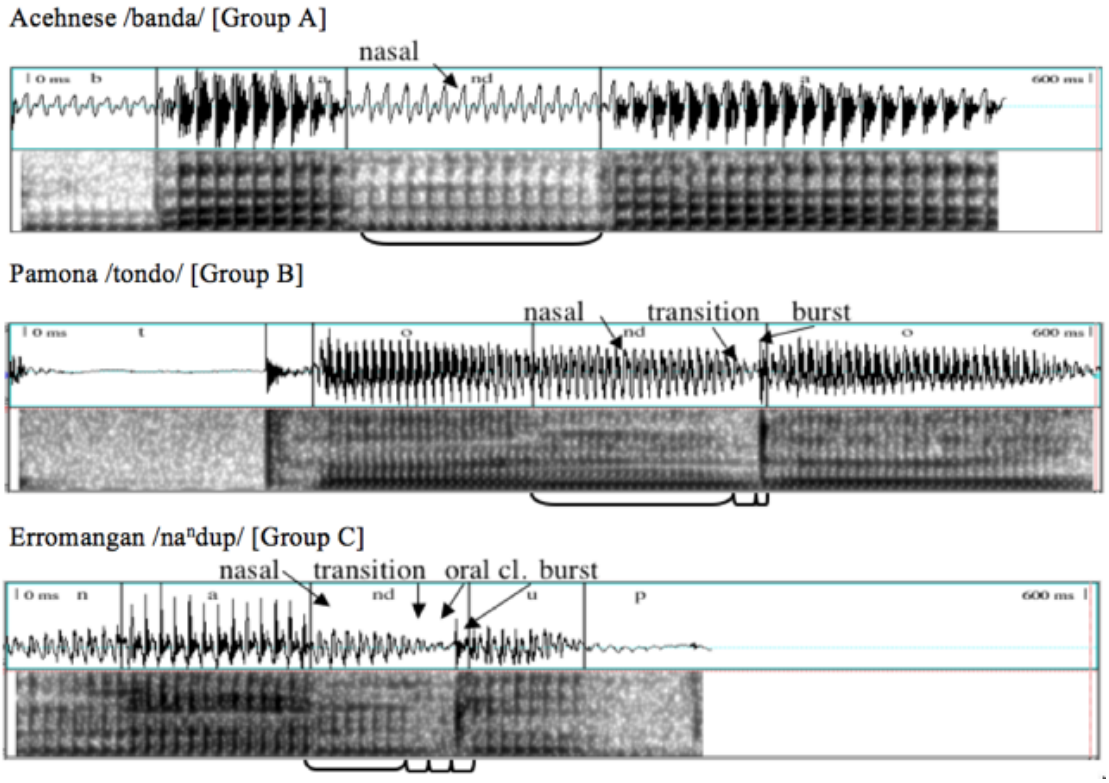

Figure 9. Spectrograms of ND sequences in three languages, illustrating groups in figure 8, with ND parts labeled

In the Acehnese token, representative of Group A, the entire duration of the ND is comprised of a steady nasal portion, with no notable transitional decrease in intensity, and no oral portion. In the Pamona token, representative of Group B, a steady nasal portion extends for most of the total duration, with a brief transition at the end where the nasal drops in intensity, followed by an oral burst. In the Erromangan token, representative of Group C, the steady nasal portion ends in a longer transition of decreasing amplitude and is followed by a brief oral closure and finally a clear burst. However, are these groups meaningful? The difficulty in determining where to draw the lines between different groups and the difficulty in characterizing the properties of the members of a group – in particular the in-between cases in Group B – suggest that they are not.

Also at issue in trying to characterize these groups is observed inter- and intra-speaker variation. While speakers of the same language largely group together, there is some scattering. For example, while three speakers of Pamona pattern together with oral cue durations of 10-20 milliseconds on average, one speaker has no evidence of any transition or oral component across all repetitions. Second, there is also variation across the tokens for an individual speaker. This variation can be observed in the preceding figures by looking at the error bars, which are based on total duration of the three components and which reveal significant deviations from the averages for some speakers. Challenging our attempt to group speakers by language is the fact that variation observed across the tokens for a single speaker is in some cases greater than the magnitude of the differences between the attempted groups. We also do not know if data from a greater number of speakers would reveal even more such variation.

In fact looking at the results this way amplifies very small differences that are not likely to be meaningful. As discussed below in 5.1, the presence or absence of a transition in

decreasing nasality – as opposed to an abrupt transition between nasal closure and oral release – may be due to slightly different aerodynamic strategies, but differences in duration of the transition are very unlikely to be meaningful in any sense. If we look at the differences in duration of the oral portions, that is closure and/or release, we see that they range in duration from 0 milliseconds to 15 milliseconds, still a very brief period.

The more important question is whether the results group by language in a meaningful way and if so where Acehnese and Sundanese fit with respect to the other four languages. Table 6 below highlights how the languages fall into the tentative groupings in figure 8 based on total duration of the three components as well as a characterization of their properties.

Table 6. Grouping of individual speakers of each language into the three microtiming groups

	Group A no oral portion	**Group B** brief/no transition short oral portion	**Group C** notable transition notable oral portion
Manado	1, 2, 3	4	
Acehnese	1, 2	3,4	
Pamona	1	2,3	4
Sundanese	1	2,3	4
Tamambo			1, 2, 3, 4
Erromangan			1, 2, 3, 4

Table 6 reveals that the speakers of a language roughly group together. This is particularly true for Erromangan and Tamambo, where all speakers fall into Group C, with all of the Erromangan speakers having notable transitions as well as notable oral closures and releases and all of the Tamambo speakers having transitions and oral releases. Acehnese and Manado Malay reveal a different pattern, with all speakers falling into Groups A or B and exhibiting little to no oral portion in their N-Ds. Pamona and Sundanese fall somewhere in between, each with at least one speaker per category; however, the N-D components in both languages tend towards shorter durations and more negligible oral portions, more similar to Acehnese and Manado Malay. Thus while it is not possible to distinguish between speakers of different languages based on microtiming data alone, speakers of the same language do tend to exhibit similar patterns.

At first blush, these data may appear to suggest that the unary-cluster distinction is unexpectedly manifested in microtiming of the oral component. The languages with unary ^{N}Ds – Tamambo and Erromangan – tend to have longer transitions than the cluster languages, as well as substantial oral portions. However, data from English, a language with undisputed N-D clusters, reveals that this is not the case. Figure 10 below displays the microtiming data for the Austronesian cases alongside data from four speakers of Canadian English. Data from three of these speakers fall within Group C along with speakers of Tamambo and Erromangan, the unary languages, while data from one speaker fall into Group B alongside the cluster languages.

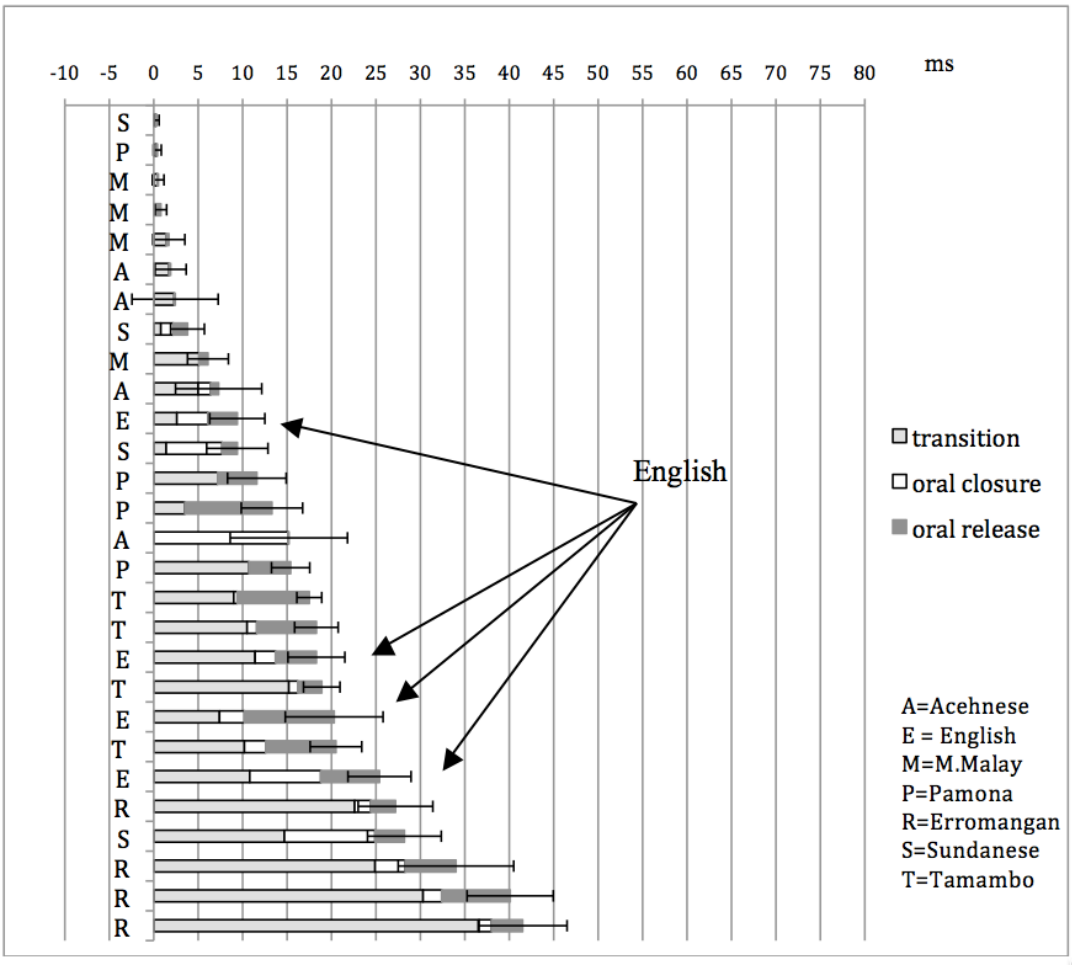

Figure 10. Microtiming results as in figure 8, with the addition of four speakers of English

Our discussion of microtiming of the ND sequences leads us to the following conclusions. First, the so-called "post-stopped" nasals of Acehnese and Sundanese are not notably different from the NDs of other languages. Although they tend to be at one end of the continuum in terms of having briefer transitions and oral components, it is not possible to distinguish them from the N-D clusters of Manado Malay nor Pamona. Second, microtiming patterns do not distinguish unary and cluster NDs. On the whole, in our six Austronesian languages, the N-D clusters tend to have shorter transitions and oral portions than the unary ^{N}Ds; however, our consideration of some additional data from English reveal that N-D clusters can also have more substantial oral portions. Third, although speakers exhibit variation across repetitions, and although it is not possible to cleanly group speakers by language, the speakers of a language do tend to have similar patterns. Fourth, all of the Western Austronesian cluster languages tend to fall on the shorter end of the spectrum in terms of having more negligible transitions and oral portions.

The data presented in this section are all from medial alveolar NDs. We have also analyzed initial alveolar NDs in the languages that allow them: Acehnese, Pamona, Tamambo, and Erromangan, and we find the same general patterning and characteristics with regard to transitions and oral cues. Preliminary results for bilabials suggest that, across languages, bilabials may have more substantial oral portions, but there appear to be no substantive differences in terms of phonological patterning. Nevertheless, a larger study that examines various places of articulation in detail would be valuable.

4.5 Summary

In this section, we examined the total duration and relative internal timing of N-D clusters in Acehnese and Sundanese and determined that they have the same patterns as the N-D clusters in Manado Malay and Pamona. In terms of total duration, the N-Ds in these languages are at least 1.36 times longer than plain nasals, in most cases much longer, in keeping with the cluster rather than the unary pattern. In terms of relative internal timing, most of the N-D duration in these languages consists of a nasal closure with only a negligible oral portion, which is the pattern of all NDs we have examined, whether unary or cluster. We illustrate these findings in figure 11 below, which is an updated version of figure 4 but with the removal of the "post-stopped nasal" category. The figure makes clear that for the languages under investigation there are only two phonological ND categories: prenasalized stops and clusters.

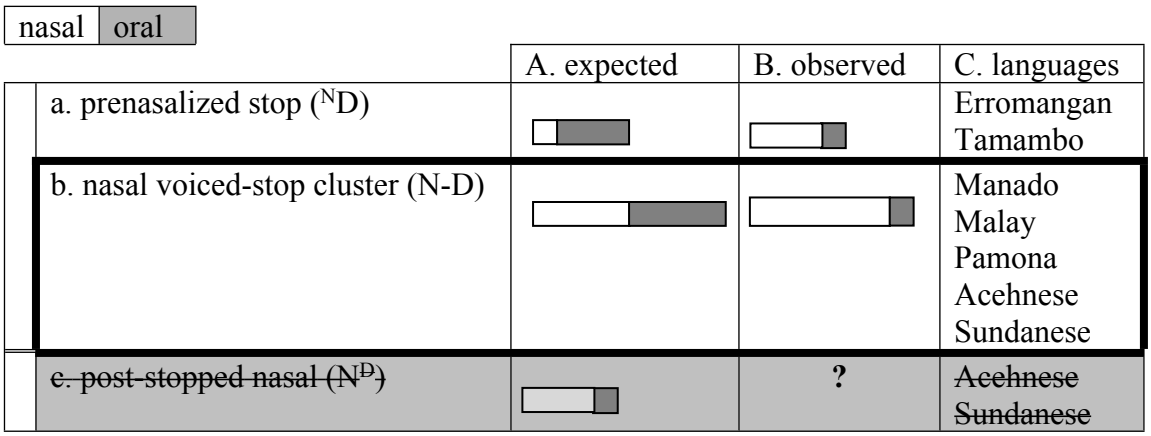

Figure 11. Expected and observed phonetic timing relationships of ND sequences, final revised version of figure 4

Upon concluding that the Acehnese and Sundanese N-Ds are clusters rather than so-called post-stopped nasals, we questioned whether or not there are other possible differences in the details of their nasal-oral timing that have warranted their description in the literature as unique sequence-types. We therefore undertook the microtiming study presented in 4.4. Our examination of measurements of nasal transition, oral closure and oral release in the NDs of four speakers of each of the six languages did not reveal any unique patterning in the N-Ds of Acehnese and Sundanese nor any robust difference between the two phonological categories – unary vs. cluster. The findings do, however, suggest that speakers of all four Western Austronesian languages tend to have more negligible transitions and oral portions than speakers of the two Oceanic languages and of English. Whether or not the pattern observed in these four Western Austronesian cases is found more generally across the language family and if so whether or not this distinguishes it from other groups is an intriguing area for future research.

Since our microtiming study revealed that the presence of an oral portion in an ND is brief for all speakers and nonexistent for some, we are left to wonder about the contrast between plain nasals and ND sequences. We turn to the issue of perceptual salience of NDs vs. plain nasals in the next section and then explore the possible implications of this for pathways to change.

5. Implications for maintaining contrast

In this section we pursue three issues suggested by the acoustic results discussed in section 4. First, in 5.1 we discuss the issue of perceptual salience of the components of ND sequences and in particular how contrast between plain nasal vs. NC sequences is

maintained. The implications of these findings lead us to consider what pathways to change from ND clusters to unary N^Ds would look like in 5.2. This in turn leads us back to the question posed in the introduction about the implications of such entities for a typology of ND entities in 5.3.

5.1 Plain nasals vs. ND sequences

An important question raised by our data is how ND sequences are distinguished perceptually from plain nasals. In all of our cases, the ND closures are almost entirely nasal, giving them the appearance of plain nasals in spectrograms (for example the Manado Malay token in figure 2 and the Acehnese token in figure 9). How are these sequences perceived as NDs rather than plain nasals? The answer is in the presence or absence of nasality on the following vowel.

In all of the languages under investigation, following plain nasals, there is strong perseverant vowel nasalization for the full duration of the vowel. This is part of the widely cited case of long distance nasal spread, whereby a string of vowels or laryngeals may be nasalized following a nasal consonant, observed in these and other Austronesian languages (see Cohn 1990 for discussion of nasal spread in Sundanese and Cohn 1993 for a survey of such cases). In contrast, following NDs, the vowel is completely oral, quite crisply so. This difference is illustrated for Tamambo and Manado Malay with nasal airflow traces shown in figure 12.

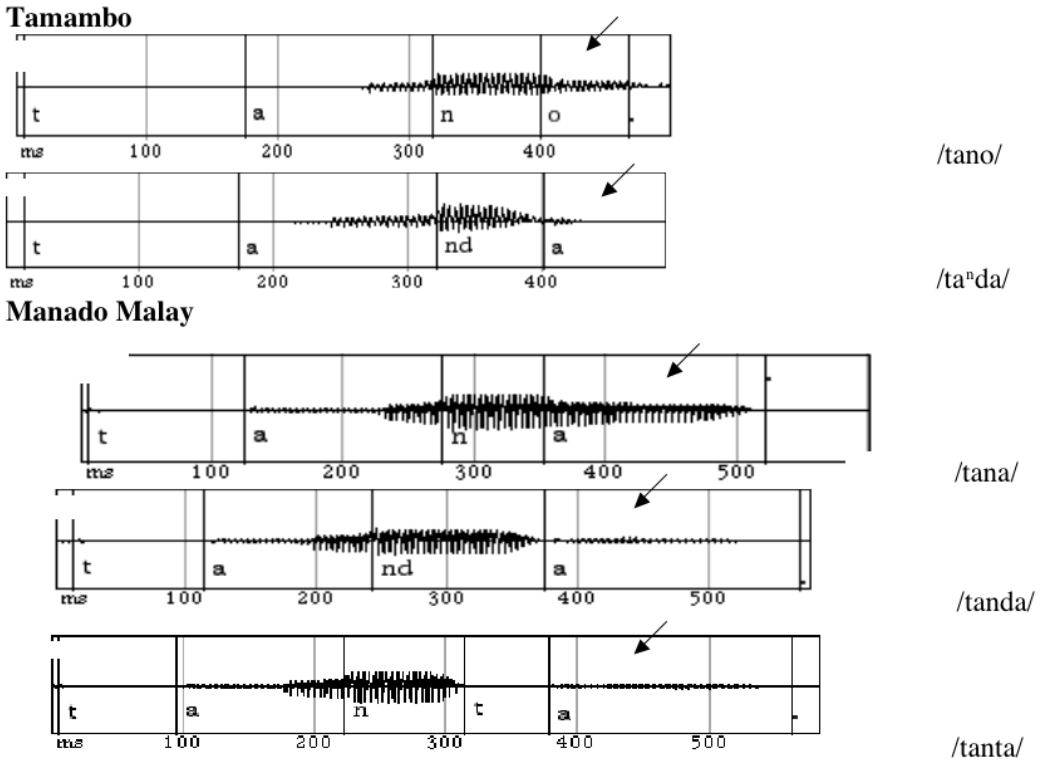

Figure 12. Nasal airflow data from Tamambo and Manado Malay, illustrating differences in nasal airflow in vowels following plain nasals and NC sequences. (Adapted from Riehl 2008.)

These observations suggest that a perceptually salient cue or possibly the most salient cue to whether the consonant is a plain nasal or ND sequence is the orality/nasality of the following vowel. Describing Sundanese, Robins (1957:91) states “In such cases [nasal voiced-stop clusters] absence of nasality in the vowel following the plosive or affricate was found to be a more readily noticeable mark of the nasal+voiced consonant sequence

as distinct from a single intervocalic nasal consonant." Durie (1985) makes similar observations for Acehnese.

Experimental support for the salience and critical importance of the perseverant nasalization on the following vowel in the plain nasal case comes from Beddor and Onsuwan's (2003) study of the perception of the prenasalized stops of Ikalanga. They manipulated both the duration of the oral closure portion of a prenasalized stop (in which they found that acoustically the nasal component takes up most of the total duration, consistent with our findings for similar cases) and the extent of perseverant nasalization on the following vowel. They found "In contrast, at least for these stimuli, the variation in coarticulatory vowel nasalization was both *necessary and sufficient* for listeners to differentiate /m/ and /^{m}b/" (Beddor & Onsuwan 2003:409).

Looking at the Western Austronesian cases in particular, one could imagine that another possible perceptual cue distinguishing ND and N is total duration: NDs are longer than plain nasals. Yet the evidence suggests that this might not be a salient cue. First, the ND vs. N contrast is maintained in prenasalized cases without a total duration difference, illustrating that a duration difference is not necessary to distinguish ND sequences from plain nasals. Second, none of the four Western Austronesian languages considered here have a phonological length contrast. Based on her finding that across the languages of the world, no language has been reported to have a unary-cluster ND contrast in the absence of a phonological length distinction, Riehl (2008) hypothesizes that a difference in length of the nasal closure is not a sufficient cue unless there is a phonological length contrast in the language more generally (such as the case in Sinhalese). A perceptual study similar to the one undertaken by Beddor and Onsuwan but also manipulating duration of the nasal closure would further inform this issue. Nevertheless, based on our observations of the data and the experimental work by Beddor and Onsuwan, we conclude that the ND vs. N distinction is maintained by a difference in orality/nasality of the following vowel, irrespective of the nasal closure duration.

Although the articulatory goal of producing an oral vowel following an ND sequence is the same for all of our cases, the microtiming data suggest that there may be different strategies for achieving this goal. For example, one strategy may be the gradual build-up of supraglottal pressure resulting in a burst. Such a strategy will result in a microtiming pattern at the "long" end of the spectrum, with an identifiable nasal transition and burst. This appears to be the case for Tamambo, Erromangan and English, and for at least one speaker each for three of the other languages. A slightly different strategy might result in a microtiming pattern at the "short" end of the spectrum, where transitions and oral portions are not present, but a very crisp onset of orality coinciding with the start of the following vowel is observed. This is the explanation offered by Ladefoged and Maddieson (1996:103-106) in their discussion of Acehnese based on pressure and airflow data. Their findings were consistent with Durie's (1985)'s finding that the "orally released nasals" (the N-D clusters) have a lesser rate of nasal airflow than "plain" nasals. "We infer that the mechanism for producing such orally released nasals and preventing the spread of nasality to the following vowel involves lowering the velum to a lesser degree than in the ordinary nasals, as well as timing the whole velum-lowering gesture to coincide quite precisely with the duration of the oral articulation involved." Interestingly they also observe consistently longer duration of the N-D as compared to the ordinary nasal, as does Durie (1985). They attribute this longer duration to a possible phonetic mechanism to achieve the observed precise timing. However, a much more straightforward interpretation is that this is a direct result of the cluster status of these sequences. To further understand the aerodynamics, oral air pressure data would be

needed. However the crucial point here is that for all tokens for all speakers there is a crisp transition to an oral vowel. Thus based on the available evidence, it does not seem that an aerodynamic strategy difference alone could be the basis of a phonological difference.

That duration of the nasal closure alone may not be a salient perceptual cue, in the absence of a length contrast in the language, suggests that the duration difference between plain nasals and N-D clusters might erode over time, meaning that what were N-D clusters could potentially become unary. We pursue this possibility by considering possible paths to change in the structure of ND sequences in section 5.2 and then consider whether there could be a difference between unary post-stopped nasals and prenasalized stops in section 5.3.

5.2 Pathways to change: ND to N^D?

The results of the present study do *not* support the conclusion that the ND sequences of Acehnese and Sundanese have become unary elements. However, if over time, the duration of the NDs shortened, resulting in N:ND ratios more like Tamambo and Erromangan than Manado Malay and Pamona, potentially they might be reanalyzed by speaker-hearers as unary, given a concurrent shift in phonological patterning. Based on impressionistic data, it has been argued that some languages in the Western Austronesian subfamily spoken in Indonesia, particularly a number of local varieties of Malay spoken in Sumatra, are undergoing such changes. While we cannot reach reliable conclusions without looking at phonological patterning and phonetic data that systematically compare plain nasals and ND sequences, it is nevertheless instructive to think about what the outcome of such a shift would be. We consider briefly what such a pathway to change might look like. Crucially both phonological and phonetic restructuring would be involved.

First the prerequisite to such a change is the absence of an independent length contrast in these languages, meaning that the longer duration of the ND closure would not be anchored as a cue to the ND vs. N contrast and a shift in N:ND ratio could set up the phonetic context for a reanalysis. However, such a change would also require phonological reanalysis. Phonotactically in both Acehnese and Sundanese, the N-D sequences pattern together with other medial clusters in the language, notably with the N-T clusters. As discussed above they occur only medially in Sundanese and primarily medially in Acehnese with very limited word-initial cases. Even if the nasal closure of the N-D sequences shortened, they would still be phonotactically parallel to N-T clusters. What might lead to a reanalysis? And what would evidence of such a reanalysis look like? It seems that the medial ND sequences would need to be clearly syllabified as tautosyllabic. An increase in the number of initial NDs, which would necessarily be analyzed as tautosyllabic (in the absence of any evidence of the nasal being syllabic) could serve as a model for medial NDs to be interpreted as being tautosyllabic. If both initial and medial NDs were consistently interpreted as tautosyllabic and there were a shortening of the N:ND ratio, the ND clusters might be restructured and reinterpreted as unary. These steps are schematized in table 7, and we consider briefly possible evidence for each of these stages:

Table 7. Possible pathway from ND cluster to unary

Prerequisite to change:	No independent length contrast
Word structure:	Increase in incidence of word-initial $ND (due to borrowing, morphology, phonological reduction)
Phonological restructuring:	Medial NDs analyzed as tautosyllabic $ND
Phonetic change:	Shift in N: ND ratio from ~ 1:1.5 → 1:1.1

Note that a reanalysis of N-D as unary, but not a reanalysis of N-T (a scenario we note in section 2.1 does not occur), would leave gaps in the phonology whereby plain nasals could only be followed by voiceless stops. This pattern is described, for example, in Wolof (Bell 2003), where the asymmetry serves to enforce the unary analysis of the NDs.

An increase in initial NDs: This might happen under influence of languages in contact, for example if there were borrowings from a neighboring language where the NDs occurred initially. Interestingly one word-initial ND form – *mbak* 'Miss' from 'older sister' – has become common in local varieties of Malay and Indonesian due to borrowing from Javanese. An increase in initial forms could also happen through truncation (again perhaps through contact with neighboring languages), such as [ndaʔ], as a variant of [tidaʔ] 'no, not' in Manado Malay. It could also happen due to morphophonemic alternations, for example the variant of allomorphs of the Active prefix N- before voiced stops in Javanese observed in many local varieties of Malay results in initial NDs.

Medial NDs interpreted as tautosyllabic: Adisasmito-Smith (2004) gives compelling phonological and phonetic evidence that the medial N-Ds in Javanese are best analyzed as tautosyllabic clusters. Word-initially these would also be assumed to be tautosyllabic, unless there were evidence of the nasal being syllabic, which Adisasmito-Smith shows is not the case in Javanese. Adisasmito-Smith investigated the possibility of such a restructuring in Javanese-influenced Indonesian as compared to Jakarta Indonesian. Interestingly, she finds that phonologically the evidence suggests the medial N-Ds and N-Ts in colloquial Indonesian not taken to have a strong Javanese influence as exemplified by Jakarta Indonesian be treated as heterosyllabic; the phonetic cues are ambiguous with respect to syllable affiliation. (Note that her total duration measurements in both languages reveal that N-Ds are substantially longer than plain nasals, supporting a cluster analysis, whether tautosyllabic or heterosyllabic.)

Gil (2002) uses a series of language games commonly played in local varieties of Malay and Malayic languages spoken throughout Sumatra as evidence for phonological structure. Some of these can be used as evidence for syllabification of medial NC clusters, and Gil notes systematic differences between varieties along these lines. Of particular relevance is a game, Sabaha, where a final syllable is reordered as the first ($ba_{\sigma 1}ha_{\sigma 2}sa_{\sigma 3}$ → $sa_{\sigma 3}ba_{\sigma 1}ha_{\sigma 2}$). Gil (2002:5) notes for the form *mintak* [mintaʔ] 'request', one native speaker of Minangkabau from Padang consistently produced the form [ntaʔmi], suggesting a $NC syllabification, while two speakers of other Sumatran varieties of Malayic produced the form [taʔmin], suggesting a N$C syllabification.

Shortening of the N:ND ratio: A possible case of shortening of the N:ND ratio is seen in Jambi Malay. Jambi Malay presents a particularly interesting case as the phonological evidence suggests a difference between two closely related varieties in precisely this

regard. Yanti (2010) provides an in-depth investigation of the closely related dialects of Jambi City and Rural Jambi as spoken in Tanjung Raden and Mudung Darat and finds a number of systematic differences in phonological patterning between the City and Rural varieties. Yanti argues that the historical N-D clusters, while still synchronically clusters in City Jambi are better analyzed as unary in Rural Jambi, for example, *tamba* 'add' – City Jambi [tamba], Rural Jambi [tam^{b}a]; *tando* 'sign' – City Jambi [tando], Rural Jambi [tan^{d}o]. Durvasula (2009), based on a study of the rural variety as spoken in Tanjung Raden, also argues that the NDs should be treated as unary and notes that this accords with speakers' intuitions about these entities.[5] The fact that unary NDs in the rural dialect occur in initial and medial position but not final position might be taken as suggestive of unary status. However, N-T clusters also occur in initial and medial but not final position, and the distribution of the ND sequences is similar in the two varieties, despite the suggested difference in phonological structure.

One source of evidence for the structural difference in NDs between the two dialects comes from different patterns of truncation where only the final syllable is used, for example, *Endang* is [daŋ] in Jambi City but [n^{d}aŋ] in Jambi Rural, and *pendek* is [deʔ] in Jambi City but [n^{d}eʔ] in Jambi Rural. While highly suggestive of a structural difference between the NCs (unary vs. cluster), the difference could also be due merely to differences in how these clusters are syllabified, with NCs forming tautosyllabic onsets in Jambi Rural (pe.ndeʔ) but not Jambi City (pen.deʔ). An investigation of phonetic data for both varieties would be of particular interest to see whether these phonological patterning differences correlate with expected N:ND ratio differences. One sample spectrogram of a medial ND presented by Durvasula (2009) shows no oral closure or release, but no duration data are presented.

Fuller investigation of both the phonological differences observed by Yanti between the Rural and City varieties as well as systematic phonetic study of both varieties is needed. The case of Jambi NDs is of particular interest because it highlights the sorts of systematic differences that can be found in closely related dialects, which in turn potentially sheds light on the incremental nature of historical change. While from the point of view of the structure of ND sequences, City Jambi appears to be more conservative, that is, representative of the historical source of these clusters, whereas Rural is more innovative, in fact the situation is more complex. As discussed by Yanti, City Jambi is emerging as a regional Koiné and as such involves some leveling of dialect differences; it is also more influenced by Indonesian and other varieties of Malay spoken in the area.

5.3 N^{D} vs. ^{N}D

Pursuing the findings of Yanti (2010) where closely related dialects of Jambi Malay potentially evidence a structural difference in their ND sequences as either N-D clusters or as unary NDs, we return to the original question of what the difference between prenasalized stops and unary post-stopped nasals might be. Would such unary post-stopped NDs be phonetically distinct from prenasalized stops? And if so could they be in contrast with prenasalized stops?

Overall our results suggest that there are not sufficient phonetic differences amongst the NDs we have examined to serve as the possible basis for a phonological contrast. Most importantly all ND sequences known to us share the property of being nasal for most of their duration, with only very brief oral components. Based on the available phonetic

[5] We do not pursue Durvasula's (2009) proposal that these sequences should be treated as phonological "obstruent nasals", as this would take us well beyond the scope of the present discussion.

data, we know of no ND sequences appropriately transcribed as [^{N}D]. This is the case for every Austronesian case known to us and also English and French (as shown by Cohn 1990), as well as the Bantu cases known to us (as discussed by Beddor and Onsuwan 2003, Maddieson and Ladefoged 1993, among others). Indeed, N-D clusters would be more accurately transcribed as [N:^{D}] and prenasalized stops as [N^{D}], rather than the common transcription of [^{N}D]. Put another way, the unequivocally unary ND sequences *are* post-stopped nasals.

Our results of the microtiming of the nasal transitions and oral portion of both unary and cluster NDs further strongly suggest that there could not be a contrast between post-stopped nasals and prenasalized stops, since we do not believe that there would a stable systematic phonetic difference between these two cases that would serve as the basis of a contrast. We saw above that the nasal-oral timing structures of N-D clusters in the four Western Austronesian languages under study here and the two Oceanic languages with prenasalized stops were not systematically distinguishable. It was suggested that slightly different aerodynamic strategies might be used in the "shorter" vs. "longer" cases, something requiring more systematic aerodynamic study to confirm. Even so, we conclude that such an aerodynamic difference could not serve as the basis of a contrast. As well, given the variability seen within languages and within speakers, the longer vs. shorter cases may simply be a matter of individual variation. Furthermore, when we consider the pathways to the development of these two types it is hard to envision a series of historical changes such that both types could arise in a single language. The canonical pattern of historical development of prenasalized stops is through nasalization of a series of voiced stops, typically in languages without NC clusters (see Riehl 2008). The hypothesized path under discussion here is one that might arise through a restructuring of N-D clusters in languages in which such clusters are systematically in contrast with both plain voiced stops and plain nasals.

6. Conclusions

The aim of this paper has been to examine claims that the ND sequences in Acehnese and Sundanese constitute a unique phonological segment, the "post-stopped nasal". We have determined, on the basis of both phonological and phonetic evidence, that they do not, but rather, that the Acehnese and Sundanese NDs are clusters. These sequences pattern like clusters in the phonology, and in the phonetics they exhibit the total duration of clusters rather than of single segments, in line with cross-linguistic observations.

Our exploration of details of the relative timing of the nasal and oral components reveals that the NDs in Acehnese and Sundanese are also not systematically distinct from other closely related languages in their finer phonetic details. Although they tend to have negligible oral components and are distinguished almost solely by the presence of a following oral vowel (which may have led to their initial descriptions as unusual nasals), these characteristics are shared by the NDs in other languages as well, including English. In considering microtiming patterns across all six Austronesian languages, we observed that the four Western Austronesian languages of Indonesia have briefer nasal transitions and oral components than the two Oceanic languages of Vanuatu as well as English. It may be that these components tend to be even more negligible in the Western Austronesian cases than others; however, much more comparative research is needed to make such a determination. Even if these languages are found to be marked cross-linguistically in this respect, it would not mean that these NDs constitute a unique segment-type. Rather, in all four cases considered here, the NDs are simply phonological clusters.

Although we concluded that neither Acehnese nor Sundanese constitute cases where historical N-D clusters have been reanalyzed as unary NDs, we considered the possibility of this pathway to change. Certain Malay and Malayic varieties spoken in Sumatra are the most plausible candidates in which phonological restructuring has laid the groundwork for phonetic shortening, which could indeed result in unary NDs. However, even if further phonological and phonetic study confirms the presence of unary NDs in these languages, we believe that they would not constitute a phonological category distinct from prenasalized stops.

The microtiming data reveal another interesting issue in terms of possible diachronic change. Given that the orality of the following vowel is the key to ND identity and that an actual oral component is not required in the ND itself, a phonological ND contrast could in theory shift from the consonant sequence to the following vowel. Some allophonic variation in Jambi and Rejang (as noted by Yanti 2010 and Coady and McGinn 1982, respectively) is suggestive in this regard; however, we do not yet know of a case where such a change as been phonologized.

Past descriptions of the ND sequences in Acehnese and Sundanese, such as those referring to "funny", "postploded", "post-occluded" or "post-stopped" nasals, when viewed in the light of the data in this paper, lead us to sound a cautionary note. Just because we can measure some property of the phonetics does not mean that it can or does indicate a phonological contrast. The details of the phonetic implementation of the perceptual goals have been assumed to be the goals in and of themselves, rather than the means of realizing the goals (that is, the difference in rate of airflow during an NC may reflect different means of achieving a following oral vowel, but not be indicative of different phonological entities).

While our examination of Acehnese and Sundanese N-Ds has resolved some issues, it has raised new questions. Data from additional speakers of these languages as well as from other Austronesian and non-Austronesian languages is needed to fully understand the relative nasal-oral timing of ND sequences. Will additional speakers confirm initial observations that languages have particular patterns, or will it reveal a more complex situation with further variation? In terms of ND perception and the importance of orality of the following vowel quality, new studies are needed to explore presumed phonetic targets and strategies, beyond the initial work by Beddor and Onsuwan (2003). Does total duration play a role in the perception of NC clusters and plain nasals? What are the perceptual thresholds for the duration of the oral closure in ND vs. NT cases? Finally, more aerodynamic data and modeling is needed to better understand the strategies used to reach the phonetic targets.

References

Adisasmito-Smith, Niken. 2004. *Phonetic and phonological influences of Javanese on Indonesian*. Ithaca, NY: Cornell University doctoral dissertation.

Beddor, Patrice & Chutamanee Onsuwan. 2003. Perception of prenasalized stops. *Proceedings of the 15th International Congress of Phonetic Sciences*. 407–410.

Bell, Arthur. 2003. Gemination, degemination and the role of the mora in Wolof phonology. *Working Papers of the Cornell Phonetics Lab* 15. 1–68.

Blust, Robert. 1997. Nasals and nasalization in Borneo. *Oceanic Linguistics* 36. 149–179.

Boersma, Paul & David Weenink. 2014. Praat: doing phonetics by computer [Computer program]. Version 5.4.01, retrieved 9 November 2014 from http://www.praat.org/.

Browman, Catherine & Louis Goldstein. 1986. Towards an Articulatory Phonology. *Phonology Yearbook* 3. 219–252.

Chan, Marjorie. 1987. Post-stopped nasals in Chinese: an areal study. *UCLA Working Papers in Phonetics* 68. 73 – 119.

Chan, Marjorie & Hongmo Ren. 1987. Post-stopped nasals: an acoustic investigation. *UCLA Working Papers in Phonetics* 68. 120–131.

Clements, George N. 1990. The role of the sonority cycle in core syllabification. In *Papers in Laboratory Phonology 1: Between the Grammar and Physics of Speech*, ed. by John Kingston and Mary Beckman. 283–333. New York: CUP.

Coady, James & Richard McGinn. 1982. On the so-called implosive nasals of Rejang. *GAVA: Studies in Austronesian Languages and Cultures*. 437–449.

Cohn, Abigail C. 1990. *Phonetic and phonological rules of nasalization*. *UCLA Working Papers in Phonetics 76*.

Cohn, Abigail C. 1993. A survey of the phonology of the feature [±nasal], *Working Papers of the Cornell Phonetics Laboratory* 8. 141–203. [originally circulated as UCLA ms. 1987].

Cohn, Abigail C. & Anastasia K. Riehl. 2012. The internal structure of nasal-stop sequences: Evidence from Austronesian. *Cornell Working Papers in Phonetics and Phonology*. 1–16.

Court, Christopher. 1970. Nasal harmony and some Indonesian sound laws. In S.A. Wurm & D.C. Laycock (eds.), *Pacific Linguistic Studies in Honour of Arthur Capell*. Canberra: Australian National University. (Pacific Linguistics C-13). 203–217

Daud, Bukhari & Mark Durie. 1999. *Kamus basa Acèh: Kamus bahasa Aceh: Acehnese-Indonesian-English thesaurus*. Canberra: Pacific Linguistics.

Downing, Laura. 2005. On the ambiguous status of nasals in homorganic NC sequences. In Marc van Oostendorp & Jeroen van de Weijer (eds.), *The Internal Organization of Phonological Segments*. Berlin: Mouton de Gruyter. 183–216.

Durie, Mark. 1985. *A grammar of Acehnese on the basis of a dialect of North Aceh.* Dordrecht, Holland: Foris Publications.

Durvasula, Karthik. 2009. *Understanding nasality.* Newark, DE: University of Delaware doctoral dissertation.

Eades, Domenyk C. 2005. *A grammar of Gayo: A language of Aceh, Sumatra*. Canberra: Pacific Linguistics.

Gil, David. 2002. Ludlings in Malayic languages: An introduction. To appear in *Pertemuan Linguistik Lembaga Bahasa Atma Jaya (PELBA)* 15.

Gordon, Matthew & Ian Maddieson. 1999. The phonetics of Ndumbea. *Oceanic Linguistics* 38. 66–90.

Herbert, Robert K. 1986. *Language universals, markedness theory, and natural phonetic processes.* Berlin: Mouton de Gruyter.

Ladefoged, Peter & Ian Maddieson. 1996. *The sounds of the world's languages*. Oxford: Blackwell.

Long, James B. & Ian Maddieson. 1993. Consonantal evidence against Quantal Theory. *UCLA Working Papers in Phonetics* 83. 141–147.

Maddieson, Ian & Peter Ladefoged. 1993. Partially nasal consonants. In Marie Huffman & Rene Krakow (eds.), *Nasals, Nasalization, and the Velum*. *Phonetics and Phonology 5*. San Diego: Academic Press. 329–367.

Riehl, Anastasia K. 2008. *The phonology and phonetics of nasal-obstruent sequences*. Ithaca, NY: Cornell University doctoral dissertation.

Riehl, Anastasia K. & Abigail C. Cohn. 2011. Partially-nasal segments. In Marc van Oostendorp, Colin Ewen, Elizabeth Hume & Keren Rice (eds.), *The Blackwell Companion to Phonology*. Oxford: Wiley-Blackwell. 550–576.

Robins, R.H. 1957. Vowel nasality in Sundanese: A phonological and grammatical study. In J.R. Firth, et al (eds.), *Studies in Linguistic Analysis*. Oxford: Blackwell. 87–103.

Scott, N. C. 1957. Notes on the pronunciation of Sea Dayak. *Bulletin of the School of Oriental and African Studies* 20. 509–512.

Schütz, Albert J. 1985. *The Fijian language*. Honolulu: University of Hawaii Press.

Storto, Luciana. 1999. *Aspects of Karitiana grammar*. Cambridge, MA: MIT doctoral dissertations.

Vatikiotis-Bateson, Eric. 1984. The temporal effects of homorganic medial nasal clusters. *Research in Phonetics* (Indiana University, Bloomington) 4. 197–233.

Yanti. 2010. *A reference grammar of Jambi Malay*. Newark, DE: University of Delaware doctoral dissertation.

Appendix

Language	Target initial words	Target medial words	Frame sentence
Tamambo	n: /novu/ 'stonefish' n^d: /ndovo/ 'to be rotten'	n: /tano/ 'garden' n^d: /tan^{d}a/ 'to look up'	/ku hare _____ tovona/ 'I write _____ today'
Erromangan	n: /nal/ 'mud' n^d: /ndal/ 'among'	n: /nani/ 'goat' n^d: /nan^{d}up/ 'bead tree' nt: /nantip/ 'banyan root'	/nalau amaŋku _____ ire/ 'The baby says _____ now'
Pamona	n: /neka/ *proper name* nd: /ndeki/ 'to climb'	n: /tono/ 'to knock head' nd: /tondo/ 'next to' nt: /tonto/ 'to empty out'	/mantoʔo _____ dʒa seʔi/ 'Just say _____ now'
Manado Malay	n: /naʔ/ 'child' (truncation of *anak*) nd: /ndaʔ/ 'no, not' (truncation of *tidak*)	n: /tana/ 'earth' nd: /tanda/ 'sign' nt: /tanta/ 'aunt'	/tʃumu dʒo _____ skarang/ 'Just say _____ now'
Acehnese	n: /na/ 'there is' nd: /ndap/ 'sneak by crawling'	n: /baneng/ 't.o. turtle'; /tanoh/ 'land' nd: /banda/ 'a seaport city'; /tanda/ 'sign, mark'	/lɔn pike _____ barɔˀ/ 'I thought _____ yesterday'
Sundanese		n: /sinar/ 'ray of light'; /panah/ 'bow and arrow' nd: /sindir/ 'sneer'; /banda/ 'thing'	/tulis _____ɟələs/ 'Write ____ clearly'
English		n: /bænɚ/ 'banner' nd: /bændɚ/ 'bander'	/seɪ _____ əgɛn/ 'Say _____ again'

Target words and frame sentences

Language	# of speakers	# of repetitions per form per speaker
Tamambo	5	10
Erromangan	4	10
Pamona	6	10
Manado Malay	6	10
Acehnese	4	10
Sundanese	4	10
English	4	10

Numbers of speakers and repetitions analyzed for each language